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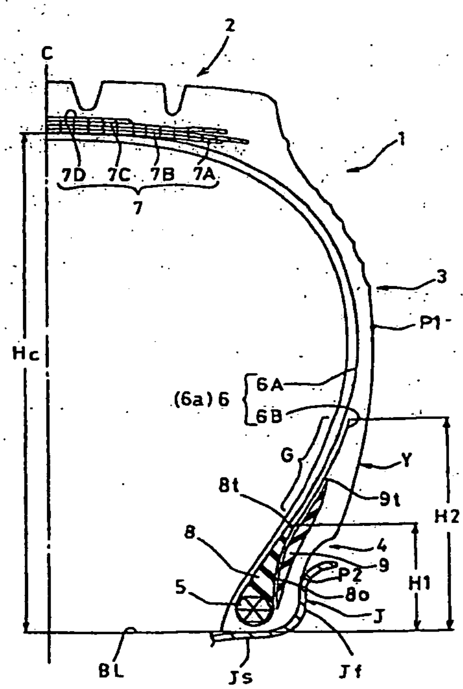
(54) **HEAVY LOAD RADIAL TIRE**

(57) A heavy duty radial tyre (1) has a carcass (6) including a carcass ply made of cords arranged at an inclination angle of 70 to 90 degrees with respect to the tyre equator, the carcass ply comprising a main portion (6A) extending from a tread portion (2) to a bead core (5) in a bead portion (4) through a sidewall portion (3) and integrally provided with a turnup portion (6B) turned up from the axially inside to the outside at the bead core (5) to extend radially outwards, and a bead apex (8) disposed between the main portion (6A) and turnup portion (6B) of the carcass ply and tapering and extending radially outwardly from the bead core (5), characterised in that the above-mentioned turnup portion (6B) extends radially outwardly along the axially outer surface of the bead apex (8) and has a parallel portion extending substantially parallel with and adjacently to the carcass ply main portion (6A) from the radially outer end (8t) of the bead apex, and the length L of the parallel portion is 1.0 to 8.0 times the maximum section width CW of the bead core (5).

Fig.1



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Description

Technical Field

[0001] The present invention relates to a heavy duty radial tyre of which the bead portions are improved in durability.

Background Technology

[0002] With the recent improvements in road networks and vehicle performance, high running performance is required even for example in heavy duty tyres for trucks, buses and the like. In recent years, radial carcass and heavy duty radial tyres in which the outside of the radial carcass is tightened by a rigid belt are widely employed. Such heavy duty radial tyres are high in rigidity of the tread portion and excellent in high speed performance, and further they show an excellent wear resistance, mileage and the like.

[0003] By the way, during running, a heavy duty radial tyre is repeatedly subjected to a large stress in the region from the sidewall portion to the bead portion. In this region, very small cracks (hereinafter referred to simply as "cracks") are liable to occur due to such stress and ozone in the atmosphere.

[0004] The cracks make it impossible to recycle the tyres, and there is a possibility that a carcass ply separation is caused if the cracks grow inwardly of the tyre.

[0005] It becomes clear that, in heavy duty radial tyres, especially those which are mounted on a five-degree-taper rim j which has bead seats j1 are tapered at five degrees with respect to the tyre axial direction as shown in Fig.12, since the outer surface of the bead portions come into contact with a curved surface j2 of the rim flange over a wide range (for example 80% or more), a large strain is produced and heat generation occurs in the contacting part during running.

[0006] Such strain and heat, by their multiplier effect, harden or deteriorate the rubber in the bead portions, which sooner causes the above-mentioned damages such as cracks, carcass ply separation and the like.

Description of the Invention

[0007] In the inventions set forth in claims 1 to 3, it is an object to provide a heavy duty radial tyre in which, by controlling cracks, especially liable to occur on the surface of the bead portion, over a long time term, the bead portions can be improved in durability

[0008] The present inventors discovered that the larger the maximum principal strain at the tyre outer surface is, the greater the possibility of cracks occurring when the tyre mounted on its regular rim is inflated.

[0009] Further, it was discovered that cracks are liable to concentrate at spots where strain is relatively large when the maximum principal strain ε m at the tyre outer surface in a region between the maximum tyre width point at which the tyre outer surface is axially outmost and an outer contact point which is the radially outmost point of a contacting region where the bead portion contacts the rim flange, and when the difference (ε m-ε p) of the maximum principal strain ε m from a maximum principal strain ε p at the above-mentioned maximum tyre width point are large.

[0010] It was discovered to be effective for controlling maximum principal strain to turn up a carcass ply a round the bead core from the axially inside to the outside to form a turnup portion, and to dispose the turnup portion adjacent to and parallel with a main portion of the carcass to form a parallel portion, and to limit the parallel portion to a length of 1.0 to 8.0 times the maximum section width CW of the bead core.

[0011] Further, in the inventions set forth in claims 4 and 5, it is an object to further improve the durability of the bead portion by preventing carcass ply separations and the like as well as cracks. For this purpose, a side packing rubber having a 100% modulus of 14 to 65 kgf/sq.cm more preferably 47 to 60 kgf/sq.cm is disposed on the axial outer surface of the carcass ply turnup portion, and the position of the radially outer end thereof is limited.

[0012] Furthermore, in the inventions set forth in claims 6 to 9, in order to further prevent the above-mentioned cracks and separations, the ratio (St/S) of a contact length St of the outer surface of the bead portion with the curved flange surface and a curved length S of the curved flange surface is set to be 0.2 to 0.70, more preferably 0.4 to 0.65.

[0013] In this specification, the "regular rim" is a rim having dimensions specified as a standard rim specified by JATMA, a "Design Rim" by TRA, or a "Measuring Rim" by ETRTO. The "regular inner pressure" is a maximum air pressure specified by JATMA, a maximum value specified in the "Tyre Load Limits At Various Cold Inflation Pressures" table of TRA, or a "Inflation Pressure" specified by ETRTO.

Brief Explanation of the Drawings

[0014]

Fig.1 is a cross sectional view (right half) of a tyre which is an embodiment of the present invention;
Fig.2 is an enlarged cross sectional view of a bead portion thereof;
Fig.3 is a view of cross section A-A of Fig.2;
Fig.4 is a graph showing the results of measured maximum principal strain;
Fig.5 is a diagram for explaining a method of measuring the maximum principal strain;
Fig.6(A) and (B) are diagrams for explaining the positions of markings;
Fig.7 is an enlarged cross sectional view of a bead portion showing another embodiment;
Fig.8 is a graph showing a relationship between the ratio (St/S) and temperature of bead portion;
Fig.9 is a partial cross sectional view for explaining an interference;
Fig.10 is an enlarged cross sectional view of a bead portion showing another embodiment;
Fig.11 is a graph showing a relationship between a ratio (f/F) and temperature of bead portion; and
Fig.12 is an enlarged cross sectional view of a bead portion of a conventional heavy duty radial tyre.

Best mode for practising the Invention

[0015] An embodiment of the present invention will now be described according to the drawings.

[0016] Fig.1 shows an assembly of a rim and a heavy duty radial tyre 1 (hereafter simply 'tyre 1') under a normal state in which the tyre is mounted on its regular rim J and inflated to its regular inner pressure and loaded with no load. The right half and left half are symmetric.

[0017] As for the above-mentioned rim J, a five-degrees-taper rim is shown in this embodiment, which comprises a rim seat surface Js tapered at five degrees with respect to a tyre axial line (a tolerance of plus/minus 1 degree is permitted) and a fixed flange Jf on one side thereof. As shown in Fig.2, the fixed flange Jf has a rim flange face Jf1 which defines the rim width and at the radially outer end a flange arc part Jf2 curved with an arc angle of substantially 90 degrees.

[0018] In Fig.1 and Fig.2, the tyre 1 comprises a tread portion 2, a pair of sidewall portions 3 extending radially inwardly from both ends thereof, and a bead portion 4 located at an inner end of each of the sidewall portions 3. Further, the tyre 1 comprises a carcass 6, which comprises a single carcass ply 6a in which a main portion 6A and turnup portions 6B are formed in one body, the main portion 6A extending from the tread portion 2 to bead cores 5 in the bead portions 4 through the sidewall portions 3, and the turnup portions 6B being turned up around the bead cores 5 from the axially inside to the outside. It is helpful for reducing the tyre weight to form the carcass 6 with a single carcass ply 6a as explained above.

[0019] In the above-mentioned carcass ply 6a, carcass cords are arranged at an angle of from 70 to 90 degrees with respect to the tyre equator C. For the carcass cords, steel cords are preferably used, but organic fibre cords, e.g. nylon, rayon, polyester, aromatic polyamide and the like can be used if need be. In this embodiment, shown as the carcass 6 is an example which is made up of a ply of an array of steel cords which are rubberised with topping rubber having a 100% modulus Mt of 37 to 47 kgf/sq.cm and inclined at an angle of substantially 90 degrees with respect to the tyre equator C.

[0020] Further, a belt 7 is disposed radially outside the carcass 6 and inside the tread portion 2. As the belt 7 in this embodiment, an example of four-ply structure is shown, wherein an innermost belt ply 7A of steel cords inclined at for example an angle of about 60 plus/minus 10 degrees with respect to the tyre equator C and belt plies 7B, 7C and 7D of steel cords inclined at small angles of not more than 30 degrees with respect to the tyre equator C are disposed one upon another so that, for example, at least two plies cross each other.

[0021] In the belt 7, other cord materials such as rayon, nylon, aromatic polyamide, nylon and the like can be used according to the need.

[0022] In the above-mentioned bead portion 4, a bead apex 8 made of hard rubber tapering radially outwards from the bead core 5 is inserted between the main portion 6A and turnup portion 6B of the carcass ply 6a. The radial height H1 of the bead apex 8 measured from the bead base line BL to the outer end 8t as shown in Fig.1 is 6 to 35%, preferably 8 to 25%, more preferably 15 to 25% of the carcass section height Hc. In this embodiment, it is set at about 21%.

[0023] The 'bead base line BL' is defined as an axial line passing through the position corresponding to the rim diameter under the above-mentioned normal state. The 'carcass section height' is defined as the radial distance from the bead base line BL to the radially outer extreme end of the carcass 6 under the normal state.

[0024] The bead apex 8 in this embodiment is preferably made of rubber having a 100% modulus Ma of from 14 to 84 kgf/sq.cm, preferably 55 to 84 kgf/sq.cm, more preferably 64 to 84 kgf/sq.cm, and as shown in Fig. 2, the axial outer surface 8o is defined by an axially inwardly swelling smooth arc.

[0025] If the 100% modulus Ma of the bead apex 8 is more than 84 kgf/sq.cm, the rigidity of the bead portion 4 becomes excessively high, and the carcass cords can be easily bent partially near the radially outer end of the bead apex 8. Thus, there is a tendency that the carcass cord strength is decreased and ply looseness is caused. If the 100% modulus Ma of the bead apex 8 is less than 55 kgf/sq.cm, the necessary rigidity for the bead portion 4 can not be obtained, and there is a tendency for the steering stability to decrease greatly.

[0026] As for the bead core 5 in this embodiment, it comprises in this example a single steel wire which is spirally wound a predetermined number of times and bunched into a substantially hexagonal section shape. The periphery thereof is coated with rubber. As shown in Fig.2, the radially inner side 5i of the bead core 5 extends along a axial line. Since the tyre 1 is mounted on a five-degree-taper rim, the inside diameter ϕ A of the bead core 5 at the above-mentioned inner side 5i must be larger than the nominal diameter ϕ B of the regular rim J.

[0027] If the inside diameter ϕ A of the bead core 5 is less than the nominal diameter ϕ B of the regular rim J, problems arise, for example the cords of the carcass 6 are exposed in a bead seat surface, or it can not be mounted on a regular rim. Incidentally, for the wire material of the bead core 5, aromatic polyamide can be used in addition to steel.

[0028] The above-mentioned turnup portion 6B of the carcass ply 6a is preferably ended at a position of height H2 where the strain under load is relatively small. To put it concretely, it is extended radially outwardly beyond the outer end 8t of the bead apex 8. But it is better to avoid the maximum tyre width point P1 where the outer surface of the tyre is axial outmost. These help to decrease the concentration of strain on the outer end of the turnup portion 6B and thus to prevent separation.

[0029] The above-mentioned turnup height H2 of the carcass ply 6a shown in Fig.1 is 20 to 60%, preferably 30 to 60%, more preferably 35 to 45% of the carcass section height Hc from the bead base line BL. In this embodiment it is set at about 41%. If the height H2 of the radially outer end of the turnup portion 6B is less than 30% of the carcass section height Hc, there is a tendency such that strain concentrates on the outer end of the turnup portion 6B and separations are liable to occur. If the height H2 of the radially outer end of the turnup portion 6B is more than 60% of the carcass section height Hc, the improvement in the durability reaches to its limit, and the tyre weight is increased. Thus it is not preferable.

[0030] The turnup portion 6B of the carcass ply in this embodiment extends radially outwards along the outer surface 8o of the bead apex rubber 8 while swelling inwardly first, and then approaches the main portion 6A of the carcass ply from a position substantially equal to the outer end 8t of the bead apex rubber 8, and thereafter extends substantially parallel therewith to form a parallel portion G, and finally terminates.

[0031] For example in the above-mentioned normal state, the length L of the parallel portion G (measured therealong) is 1.0 to 8.0 times, preferably 2.0 to 8.0 times, more preferably 3.5 to 6.5 times, still more preferably 4.0 to 6.0 times the maximum section width CW of the bead core 5 (measured on the wire). In this embodiment, the parallel portion G is about 5.0 times the maximum section width CW of the bead core. The parallel portion G helps to control the maximum principal strain on the outer surface of the bead portion.

[0032] In this embodiment, the parallel portion G is formed, and when the tyre condition is changed from a tentative state in which the tyre 1 is mounted on a regular rim J and inflated to 0.5 kgf/sq.cm to the normal state in which the tyre is inflated to its regular inner pressure, the maximum principal strain ε m on the surface of a region Y which region is defined between the above-mentioned maximum tyre width point P1 and an outer contact point P2 which is the radially outmost point of the contacting region of the bead portion 4 contacting with the flange Jf of the rim J is set to be not more than 4%; and further the difference (ε m-ε p) between the above-mentioned maximum principal strain ε m in the region Y and the maximum principal strain ε p at the maximum tyre width point P1 is set to be less than 2%.

[0033] It was discovered that if the length L of the parallel portion G is less than 1.0 times the maximum section width CW of the bead core, a distinct peak appears in the maximum principal strain ε m in the region Y, and cracks occur relatively early, concentrating upon the position of the peak. Contrary, if the length L of the parallel portion G exceeds 8.0 times the maximum section width CW of the bead core, the improvement in the bead durability reaches to its upper limit, and the tyre weight increases. Thus it is not preferable.

[0034] In this example, the radially inner end of the parallel portion G is located on the radially outside of the outer end of the rim flange Jf. Fig.3, which is the A-A cross section of Fig.2, shows an example in which the carcass ply turnup portion 6B is close to the main portion 6A in the parallel portion G. In the figure, the distance N between the carcass cords of the main portion 6A of the carcass ply 6a and those of the turnup portion 6B is for example set in the range of from 1.0 to 4.5 times, preferably 1.5 to 3.5 times the diameter D of the carcass cords 11.

[0035] The parallel portion G mitigates shearing force between the carcass cords of the carcass main portion 6A and turnup portion 6B by the elasticity of rubber material existing between the carcass cords, and further functions to reduce strain on the surface of the bead portion.

[0036] If the cord distance N is less than 1.0 times the carcass cord diameter D, the carcass cords 11 are apt to adjoin each other, and the shearing-force-mitigating-effect by the rubber between the cords becomes insufficient. Further, the carcass cords 11 are in danger of partially contacting each other, and thus, there is possibility of causing cord looseness. Further, if the cord distance N is more than 4.5 times the carcass cord diameter D, even when the main portion

6A and turnup portion 6B are parallel to each other, the effect to reduce the maximum strain ε on the outer surface of the region Y is apt to decrease. Further, the thickness of the bead portion 4 is increased more than is necessary, and it is not preferable from a point of view of heat generation.

[0037] As for the rubber material between the carcass cords 11, 11 in the parallel portion G, the above-mentioned topping rubber for the carcass ply 6a can be used, but in this embodiment, a separate cushion rubber layer 12 is disposed between the carcass ply main portion 6A and turnup portion 6B. For the cushion rubber layer 12, it is possible to use substantially the same rubber materials as the topping rubber and hard rubber materials having substantially the same hardness as the bead apex 8 so as to be able to reinforce the bead portion 4.

[0038] Fig.4 shows the results of measurements of a conventional tyre (tyre of Fig.12 having no parallel portion) and a tyre of the present invention, wherein the strain in the region Y between the tyre outmost point P1 and outer contact point P2 was measured. As apparent from Fig.4, in the conventional tyre, the maximum principal strain ε m in the region Y had a peak Z of 7 to 8% under the above-mentioned inflating condition change. On the contrary, in the conventional tyre, it decreased to about 2% at the tyre outmost point P1. That is, the maximum principal strain ε m was large, and the relative strain or difference (ε p-ε m) of the maximum principal strain ε p at the maximum tyre width point P1 from the maximum principal strain εm in the region Y was more than 5%, namely large.

[0039] In contrast therewith, in the tyre of the present invention, the maximum principal strain ε m could be reduced to under 4% in the whole region Y. Further, in the tyre of the present invention, since the difference (ε p-ε m) between the maximum principal strain ε m in the region Y and the maximum principal strain ε p at the maximum tyre width point P1 is limited to under 2%, the maximum principal strain ε m substantially had no peak, and the relative strain in the region Y was decreased.

[0040] Thus, in the tyre of this embodiment, the maximum principal strain on the tyre surface of the above-mentioned region Y which extends from the sidewall portion 3 to the bead portion 4 can be limited to a very small value, thereby effectively controlling cracks, caused by repeated deformation and ozone in the atmosphere, over an extended period of time. Further, a separation growing from the outer surface of the bead portion 4 toward the inside of the tyre can be prevented.

[0041] If the maximum principal strain ε m exceeds 4%, due to degradation of rubber caused by the repeated deformation of the sidewall portion during running and ozone in the atmosphere, cracks have a tendency to concentrate on a high-strain spot. Thus, it is not preferable. If there are spots in which the difference (ε p-ε m) between the maximum principal strain ε m in the region Y and the maximum principal strain ε p at the maximum tyre width point P1 exceeds 2%, the relative strain at the maximum tyre width point P1 becomes large, and cracks are apt to concentrate on this point.

[0042] Incidentally, as shown in Fig.5, the maximum principal strain ε m is measured as follows. First, the surface of the sidewall portion 3 and bead portion 4 of a test tyre is buffed and washed with naphtha. A adhesive agent is applied to the buffed surface, and a radially extending measuring reference line RL is drawn. Markings or a series of circles in white ink (titanium oxide+DOP+castor oil) are copied onto a vinyl tape 15 by means of screen printing. Then, to copy the markings, the vinyl tape 15 is applied to the buffed surface of the test tyre along the measuring reference line, wherein the tyre is mounted on its regular rim and inflated to an inner pressure of 0.5 kgf/sq.cm. Further, after the tyre is inflated to a regular inner pressure, the markings on the tyre are copied to a blank tape. The markings (under the reference condition in which 0.5 kgf/sq.cm was applied, and the comparative condition in which the regular pressure was applied), obtained as explained above, are enlarged to measure each reference point shown in Fig.6. The maximum principal strain can then be calculated from the following equations 1 to 11.

Equation 1

Under the reference condition, the circumferential length

[0043]

$$Lc0=\{(x10-x20)^2+(y10-y20)^2\}^{1/2}$$

Equation 2

Under the reference condition, the radial length

[0044]

$$Lr0=\{(x30-x40)^2+(y30-y40)^2\}^{1/2}$$

Equation 3

Under the reference condition, the length in a 135 degree direction

[0045]

$$L_{135}0=\{(x50-x60)^2+(y50-y60)^2\}^{1/2}$$

Equation 4

Under the comparative condition, the circumferential length

[0046]

$$Lc1=\{(x11-x21)^2+(y11-y21)^2\}^{1/2}$$

Equation 5

Under the comparative condition, the radial length

[0047]

$$Lr1=\{(x31-x41)^2+(y31-y41)^2\}^{1/2}$$

Equation 6

Under the comparative condition, the length in a 135 degree direction

[0048]

$$L_{135}1=\{(x51-x61)^2+(y51-y61)^2\}^{1/2}$$

Equation 7

The circumferential strain

[0049]

$$\varepsilon c=(Lc1-Lc0)/Lc0$$

Equation 8

The radial strain

[0050]

$$\varepsilon r=(Lr1-Lr0)/Lr0$$

Equation 9

The strain in 135 degree direction

[0051]

$$\varepsilon_{135}=(L_{135}1-L_{135}0)/L_{135}0$$

Equation 10

Searing strain

[0052]

$$\gamma=\varepsilon c+\varepsilon r-2X\varepsilon_{135}$$

Equation 11

The maximum principal strain

[0053]

$$\varepsilon=(\varepsilon c+\varepsilon r)/2+\{(\varepsilon c-\varepsilon r)^2+\gamma^2\}^{1/2}/2$$

[0054] In this embodiment, on the axially outer surface of the turnup portion 6B of the carcass ply 6a, a side packing rubber 9 having a 100% modulus Mp of 14 to 65 kgf/sq.cm more preferably 47 to 60 kgf/sq.cm and tapering towards the radially inner end and outer end is disposed. The radially outer end 9t of the side packing rubber terminates outside the outer end 8t of the bead apex 8 and in this embodiment inside the outer end of the parallel portion G.

[0055] As for the bead portion 4, shown is an example provided with a chafer rubber 10 covering over the axially outer surface of the side packing rubber 9 and exposing in the bead seat surface 4b and the outer surface 4a of the bead portion 4. The chafer rubber 10 preferably has a 100% modulus Mc of 55 to 75 kgf/sq.cm, more preferably 60 to 75 kgf/sq.cm. It is preferable for the chafer rubber 10 to have such a high modulus because the rigidity of the outer surface 4a and bead seat surface 4b of the bead portion 4 contacting with the rim J is suitably increased, and damages due to rim chafing and rim contacting can be effectively controlled.

[0056] By providing the outer surface of the turnup portion 6B of the carcass ply with the side packing rubber 9 and chafer rubber 10 which have 100% moduli adjusted as explained above, it becomes possible to decrease the difference in modulus at the boundary from the topping rubber of the carcass 6, and strain concentration is mitigated and the effect to prevent separations of the turnup portion 6B can be improved.
If the 100% modulus Mp of the side packing rubber 9 is less than 14 kgf/sq.cm, the ability to follow the carcass improves, but the rigidity of the bead portion decreases and the steering stability greatly decreases. On the other hand, the 100% modulus Mp of the side packing rubber 9 exceeds 65 kgf/sq.cm, the modulus difference from the topping rubber of the carcass ply 6a is liable to become large, and the separation-preventing-effect decreases. The difference between the 100% modulus Mt of the carcass cord topping rubber and the 100% modulus Mp of the side packing rubber is preferably not more than 10 kgf/sq.cm, more preferably not more than 5 kgf/sq.cm.

[0057] If the outer end 9t of the side packing rubber 9 is positioned inside the outer end 8t of the head apex 8, the strain-mitigating-effect decreases, which is due to the carcass 6 being bent relatively largely in the outer end portion 8t of the bead apex 8 during running. If the outer end 9t of the side packing rubber 9 extends outwardly so as to cover the outer end of the above-mentioned parallel portion G, it would be possible to prevent the turnup portion 6B from separating. Thus, this is preferable from this viewpoint. Further, as the radially inner end 9b and outer end 9t of the side packing rubber 9 are tapered, the rigidity difference from the surrounding rubber can be minimised to disperse the strain. Thus, this is preferable from this viewpoint too.

[0058] In this embodiment, the radially inner end 9b of the side packing rubber 9 is located on an axial line extending axially outwardly from the substantially centre of the bead core 5 as shown in Fig.2. It is preferable for effectively preventing the carcass ply turnup portion 6B from separating to set the height H3 of the inner end 9b in the range of from 1 to 8% of the carcass section height Hc, in this embodiment 4.5%. On the other hand, the outer end height H4 of the side packing rubber 9 is preferably 25 to 65% of the carcass section height Hc, in this embodiment about 31%.

[0059] Thus, in this embodiment, the bead apex height H1, the carcass turnup height H2, and the inner and outer end heights H3 and H4 of the side packing rubber satisfy a relationship

$$H3 < H1 < H4 < H2$$

but, it may be possible to satisfy

$$H3 < H1 < H2 < H4.$$

[0060] It is most effective to set the maximum thickness (t) of the side packing rubber 9 (shown in Fig.2) in the range

of from 0.2 to 0.7 times the maximum section width CW of the bead core 5. If the thickness (t) is less than 0.2 times the maximum section width CW of the bead core 5, the side packing rubber 9 has a tendency to relatively decrease its effect to prevent the carcass ply turnup portion 6B from separating. If the thickness (t) exceeds 0.7 times the maximum section width CW of the bead core 5, the rubber thickness of the bead portion 4 is liable to increase, and the heat generation there from is also liable to increases.

[0061] If the 100% modulus Mc of the above-mentioned chafer rubber 10 is less than 55 kgf/sq.cm, it is liable to become difficult to obtain such a rigidity that makes it possible to endure the contact with the rim J. If exceeds 75 kgf/sq.cm, the rigidity of the bead portion excessively increases. The chafer rubber 10 in this embodiment is connected with a sidewall rubber 14 having a 100% modulus Ms of 10 to 20 kgf/sq.cm and defining the outer surface of the sidewall portion 3.

[0062] By thus disposing the side packing rubber 9, chafer rubber 10 and the like, the rigidity of the bead portion 4 can be properly mitigated and the strain can be broadly dispersed. Thus, the separation-preventing-effect improves. The side packing rubber 9 can prevent the carcass 6 from being bent partially at the outer end 8t of the bead apex 8 and thus a decrease in the strength of the carcass cords near the outer end 8t can be avoided.

[0063] Fig.7 shows another embodiment, wherein in a tyre meridian section under the above-mentioned normal state, the outer surface of the bead portion 4 comes in contact with a flange arc surface Jf2 curved so as to have an arc angle of substantially 90 degrees and continued to the radially outer end of the rim flange surface Jf1 of a rim width part. In the example shown, the ratio (St/S) of the contact length St of the outer surface of the bead portion 4 with the flange arc surface Jf2 and the arc length S of the flange arc surface is 0.2 to 0.70. The other structures are substantially the same as the former embodiment.

[0064] In a conventional tyre mounted on a five-degree-taper rim (shown in Fig.12), as the outer surface 4a of the bead portion 4 comes in contact with the flange arc surface Jf2 broadly under the normal state and separation failures often occur in the carcass ply turnup portion. In this embodiment, therefore, the area T (shown in Fig.7) of the outer surface 4a of the bead portion 4 contacting with the flange arc surface Jf2 is specifically limited to an area smaller than the conventional one, thereby minimising the amplitude of strain and frictional heat generation caused by tyre deformation during running such that the tyre falls down towards the rim flange Jf. Thus, the occurrence of separation is further controlled by the synergism of this, the side packing rubber 9, the limited maximum principal strain and the like.

[0065] The above-mentioned range of the ratio (St/S) was obtained from the results of various tests conducted by the inventors. That is, tyres were made by way of test changing the above-mentioned ratio (St/S), and a drum durability test was conducted to measure the temperature at the inside (point A of Fig.7) of the bead portion, and the results shown in Fig.8 were obtained. It was discovered that the bead portion 4 can be decreased in heat generation and heat generation reduced to a very low level, by setting the above-mentioned ratio (St/S) in the range of from 0.2 to 0.70, more preferably 0.4 to 0.65, still more preferably 0.50 to 0.65.

[0066] If the above-mentioned ratio (St/S) is less than 0.2, the contacting area T becomes too narrow, and the bending deformation of the bead portion 4 greatly increases, and as a result, the frictional heat generation increases. Tyres having a ratio (St/S) more than 0.70 were about the same as the conventional tyres. As the contacting area T excessively increases, the heat generation and strain increases, and the separation preventing effect can not be obtained. Incidentally, if the arc angle of the flange arc surface Jf2 is not less than 90 degrees, the arc length S is defined as the length corresponding to an arc angle of 90 degrees.

[0067] Further, in this embodiment, the outer surface of the bead portion 4 forms a curved surface portion 13 which is caved in toward the inside of the tyre like an arc and extends radially outwardly from the outer contact point P2 which is the radially outmost point of the area T of the outer surface of the bead portion 4 contacting with the flange arc surface Jf2 of the above-mentioned rim flange Jf. Such an arc-like curved surface portion 13 further decreases the rubber thickness of the bead portion 4 and reduces the internal friction of the rubber to lessen heat generation, which further helps to prevent separation failures.

[0068] Because the arc-like curved surface portion 13 is formed to accord with the profile of the flange arc surface Jf2 of the rim flange Jf when fallen down toward the rim flange, the curvature is not reversed even when it is fallen down and deformed, and further the friction between the arc-like curved surface portion 13 and the flange arc surface Jf2 of the rim flange Jf becomes very small. Therefore, heat generation and strain in the bead portion 4 can be reduced, and the occurrence of separation can be controlled.

[0069] As shown in Fig.7, the height H5 of the radially outer end P3 of the arc-like curved surface portion 13 from the bead base line BL is 15 to 35%, preferably 20 to 30%, more preferably 22 to 28% (in this embodiment 21%) of the above-mentioned carcass section height Hc, and in this example, it is substantially equal to the height H1 of the above-mentioned bead apex 8. In this embodiment, the arc-like curved surface portion 9 meets the outer surface's arc C1 of the sidewall portion 4 which has a centre on the tyre hollow's side and a radius of curvature R1 so that the meeting part appears to be a circumferential crest line.

[0070] If the height H5 of the radially outer end of the above-mentioned arc-like curved surface portion 13 is lower than 15% of the carcass section height Hc, it becomes difficult to decrease the rubber thickness of the bead portion 4,

and an effect to reduce the friction between the arc-like curved surface portion 13 and the flange arc surface Jf2 of the rim flange Jf tends to decrease. If more than 30%, there is a tendency for the rigidity of the bead portions 4 to decrease. As shown in this example, it is preferable, for preventing the bead rigidity from decreasing, to dispose the outer end P3 of the arc-like curved surface portion 13 at the substantially same position as or inward of the outer end 8t of the bead apex 8 which is made of hard rubber.

[0071] Further, in the tyre meridian section, it is preferable to form the arc-like curved surface portion 13 by a single arc or a plurality of arcs. In case of a single arc, the radius of curvature thereof is preferably 20 to 30 % of the above-mentioned carcass section height Hc. Preferably, the arc-like curved surface portion 9 and the arc of the outer surface of the sidewall portion 4 are smoothly connected to each other as shown in Fig.7 by a dotted line.

[0072] If the arc-like curved surface portion 13 is constructed so, the amount of deformation of the bead portion 4 when leaning toward the rim flange Jf becomes large. In connection with the size, measured in a vulcanising mould, of conventional heavy duty tyres to be mounted on a five-degree-taper rim in particular, the inside diameter of the bead seat surface 4b is set to be larger than the outside diameter of the rim seat surface Js. Thus, there is an interference between the outer surface of the bead portion and the rim flange surface. Therefore, the bead seat surface 4b is more moved when leaning and the heat generation in the bead portion 4 increases.

[0073] Therefore, in this embodiment, with regard to the size in the tyre vulcanising mould, by setting the inside diameter of the bead seat surface 4b less than the outside diameter of the rim seat surface Js as shown in Fig.9 by a chain line, an interference is provided between the bead seat surface 4b and rim seat surface Js under the above-mentioned normal state, whereby a large movement of the bead seat surface Js when the tyre 1 is loaded can be controlled, and the heat generation in the bead portion due to repetitions of deformation can be decreased, and rubber failure in the bead base is controlled.

[0074] Thus, the durability of the bead portion can be further improved.

[0075] As shown in Fig.9, the maximum interference E between the rim seat surface Js on the fixed flange side and the bead seat surface of the tyre under the in-mould size is preferably 0.5 to 3.0 mm. If the interference E is less than 0.5 mm, the effect to control a large movement of the be ad seat surface 4b when loaded becomes decreased. If more than 3.0 mm, it becomes difficult to mount the tyre on a rim. On the other hand, it is possible to dispose a cord (fabric) chafer to reinforce the bead seat surface 4b.

[0076] Further, in this embodiment, as shown in Fig.10, under the above-mentioned normal state, the rubber thickness is adjusted as follows:

[0077] Given that point R is the intersecting point of the outer surface of the bead portion 4 and a line, a line is drawn along the minimum distance F between the axially outer surface M of the carcass turnup portion 6B and a 60 degree position P on the flange arc surface Jf2 which corresponds to a 60 degree arc starting from the radially outer end of the rim flange surface Jf1.

[0078] The ratio (f/F) of the distance (f) between points (M and R) and the length (F) of the above-mentioned line is in the range of from 0.4 to 0.9.

[0079] From the results of tests conducted by the present inventors, the following were discovered: separation failures in the bead portion 4 concentrates in the neighbourhood of the above-mentioned point M of the line extending along the minimum distance F between the 60 degrees position P on the flange arc surface Jf2 which corresponds to a 60 degree arc from the radially outer end of the rim flange Jf1 and the axially outer surface M of the carcass turnup portion 6B; and heat generation in the bead portion 4 can be controlled by adjusting the rubber thickness relatively to the length (F) of the line, that is, the distance (f) between the above-mentioned (M and R), thereby preventing separation failure.

[0080] Tyres were made changing the above-mentioned ratio (f/F), and a durability drum test was conducted to measure the temperature around the point (M). As shown in Fig.11, if the ratio (f/F) exceeds 0.9, the bead rigidity is increased, but the opportunity for contact with the rim flange Jf is increased and the heat generation increases. If the ratio (f/F) is less than 0.4, the bead portion becomes short of rubber thickness and thus the rigidity. As a result, the steering stability deteriorates, and structural breakdown can be caused.

[0081] As explained above, the controlling of the rubber thickness of the bead portion enhances the effect of the side packing rubber 9. Further, it helps to decrease the strain in the above-mentioned region Y, and the durability of the bead portion can be further improved.

[0082] A heavy duty radial tyre 1 has been detailed as above. In each of the above-mentioned embodiments, the bead portion 4 is not provided with a cord reinforcing layer separating from the carcass ply 6a and composed of a cord ply in which organic fibre cords or steel cords are arranged, which helps to decrease the tyre weight and cost. The present invention is not limited to the disclosed embodiments and can be modified variously as far as it does not deviate from the gist of the present invention.

Working Example

[0083] Heavy duty radial tyres of size 10.00R20 for five-degree taper rims were made according to the specifications

given in Table 1 (Example tyres 1 to 8 and a conventional tyre) and tested for durability of the bead portion.

[0084] Common specifications to the tyres are as follows:

Carcass

[0085]

Number of ply:	1
Cord construction:	Steel cord (3X0.20+7X0.23)
Cord angle:	90 degrees with respect to the tyre equator
Cord count:	38 /5cm (at a position on the radially inside of the bead core)

Belt

[0086]

Number of ply:	4
Cord construction:	steel cord (3X0.20+6X0.35)
Cord angle with respect to the tyre equator:	+67/+18/-18/-18 degrees from inside
Cord count:	26/5cm

[0087] First, changing the length of the parallel portion, the maximum principal strain in the above-mentioned region Y, crack occurrence, and bead durability were compared with each other.
In this test, a side packing rubber was not disposed, and the moduli of the different rubbers were as follows:

100% modulus Ms of Sidewall rubber:	15 kgf/sq.cm
100% modulus Ma of Bead apex rubber:	75 kgf/sq.cm
100% modulus Mc of Chafer rubber:	71 kgf/sq.cm
100% modulus Mt of carcass topping rubber:	42 kgf/sq.cm

[0088] The tests are as follows.

Durability of bead portion

[0089] A test tyre mounted on a 7.50X20 standard rim and inflated to 1000 kPa and loaded with 9000 kgf was run on a drum at a speed of 20 km/h, and when any visible damage was caused, the running was stopped. And the ratio L1/L0 of the damage-occurring distance L1 to the target distance L0 of 10000 km was evaluated by an index based on the conventional tyre being 100. The larger the value, the better the performance.

Maximum principal strain measuring test

[0090] As explained above, the existence of a peak and the maximum principal strain ε m, ε p were evaluated. (Standard rim: 7.50X20, Inner pressure: 800 kPa).

Crack test

[0091] The test tyre mounted on a 7.50X20 standard rim and inflated to 800 kPa was put in an ozone chamber where the ozone concentration was 40 pphm, and the temperature was 40 degrees, and the time spent until cracks occurred in the above-mentioned region Y was evaluated by an index based on the conventional tyre being 100. The larger the value, the better the resistance to cracking.

Tyre weight

[0092] The weight of a tyre was measured, which is indicated by an index based on the conventional tyre being 100. The test results are shown in Table 1.

Table 1

	Ex.1	Ex.2	Ex.3	Ex.4	Ex.5	Ex.6	Conv.1
Length of Parallel portion L (mm)	68	20	117	39	26	104	0
Max. section width of Bead core CW (mm)	13	13	13	13	13	13	13
L/CW	5.2	1.5	9.0	3.0	2.0	8.0	0
Shape of Bead portion	Fig.2	Fig.2	Fig.2	Fig.2	Fig.2	Fig.2	Fig.12
Max. Principal strain ε m (%)	2.5	3.5	2.5	2.5	3.0	2.5	6.5
ε m - ε p (%)	0.5	1.5	0.5	0.5	1.0	0.5	4.5
Crack test (index)	130	105	130	130	125	130	100
Bead durability test (index)	120	70	120	115	105	120	100
Tyre weight (index)	95	92	103	94	93	101	100

[0093] Next, similar tests were conducted, providing a side packing rubber and changing the rubber moduli as shown in Table 2. The test results are indicated by an index based on the conventional tyre 2 being 100. The test results are shown in Table 2, Table 3.

Table 2

	Ex. 7	Ex. 8	Ex. 9	Ex. 10	Ex. 11	Ex. 12	Ex. 13	Ex. 14	Conv. 2
H1/Hc ratio Bead apex (%)	25	25	25	25	25	25	25	25	41
H2/Hc ratio Carcass turned up portion (%)	41	41	19	61	41	41	41	41	
Side packing rubber									
H3/Hc ratio Inner end height (%)	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	-
H4/Hc ratio Outer end height (%)	31	31	31	31	31	31	31	31	-
100% modulus (kgf/sq.cm)									
Ms Sidewall rubber	15	15	15	15	15	15	15	15	15
Mp Side packing rubber	50	50	50	50	50	50	10	70	-
Ma Bead apex	75	75	75	75	75	75	75	75	75
Mc Chafer rubber	71	80	71	71	71	71	71	50	71
Mt Carcass topping rubber	42	42	42	42	42	42	42	42	42
St/S ratio Contact between Outer surface Of bead portion and Flange arc surface (%)	58	58	58	58	19	71	58	58	89
f/F ratio Rubber thickness in Bead portion (%)	80	80	80	80	80	80	80	80	100
L/cw ratio Length of Parallel portion	5.0	5.0	1.8	1.0	5.0	5.0	5.0	5.0	-
Q/D ratio Carcass cord spacing	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.0
Max. principal strain ε m in Region Y (%)	3	3	3	3	3	3	3	3	8.5
(ε m-ε p) (%)	1	1	1	1	1	1	1	1	5
Interference of Bead seat surface (mm)	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0
Durability of Bead portion (index)	200	105	115	150	125	130	101	102	100
Crack Test (index)	300	300	300	300	300	300	300	300	100
Tyre weight (index)	92	92	90	93	90	95	92	92	100

* Hc = Carcass section height

[0094] Furthermore, similar tests were made, changing the rubber moduli and the above-mentioned ratio (St/S). The test results are shown in Table 3.

Table 3

	Ex.15	Ex.16	Ex.17	Ex.18
H1/Hc ratio Bead apex (%)	25	25	25	25
H2/Hc ratio Carcass turned up portion (%)	41	19	61	41
Side packing rubber				
H3/Hc ratio Inner end height (%)	4.5	4.5	4.5	4.5
H4/Hc ratio Outer end height (%)	31	31	31	31
100% modulus (kgf/sq.cm)				
Ms Sidewall rubber	15	15	15	15
Mp Side packing rubber	50	50	50	50
Ma Bead apex	75	75	75	75
Mc Chafer rubber	71	71	71	71
Mt Carcass topping rubber	42	42	42	42
St/S ratio Contact between Outer surface of bead portion and Flange arc surface (%)	58	58	58	58
t/F ratio Rubber thickness in Bead portion (%)	80	80	80	30
L/cw ratio Length of Parallel portion	5.0	1.8	6.0	5.0
Q/D ratio Carcass cord spacing	2.5	2.5	2.5	2.5
Max. principal strain εm in Region Y (%)	3	3	3	3
(ε m-ε p) (%)	1	1	1	1
Interference of Bead seat surface (mm)	1.5	1.5	1.5	1.5
Durability of Bead portion (index)	200	115	150	125
Crack Test (index)	300	300	300	300
Tyre weight (index)	92	90	93	90

* Hc = Carcass section height

[0095] From those test results, it was confirmed that Example tyres was improved in the durability of the bead portion.

[0096] Further, it was confirmed that Example tyres have no peak of the maximum principal strain ε m in the region Y and the value thereof is not more than 4.0%.

[0097] Furthermore, it was confirmed that ε m-ε p is less than 2% and the relative difference in strain is decreased.

[0098] It may be understood that Example tyres are superior in the resistance to crack with relation to those results.

[0099] Further, as to other tyre sizes, similar good test results could be obtained.

Claims

1. A heavy duty radial tyre (1) comprising a carcass including a carcass ply (6) made of cords arranged at an inclination angle of 70 to 90 degrees with respect to the tyre equator, the carcass ply (6) comprising a main portion (6A) extending from a tread portion (2) to a bead core (5) in a bead portion though a sidewall portion (3), the main portion (6) integrally provided with a turnup portion (6B), the turnup portion (6B) turned up from the axially inside to the outside at said bead core (5) and extending radially outwardly, and a bead apex (8) between the main portion (6A) and turnup portion (6B) of the carcass ply (6) extending and tapering radially outwardly from the bead core (5), characterised in that said turnup portion (6B) extends radially outwards along the axially outer surface of said bead apex (8), and then from the radially outer end (8t) of the bead apex it has a parallel portion extending substantially parallel with and adjacently to the main portion (6A) of the carcass ply (6), and the length L of the parallel portion is 1.0 to 5.0 times the maximum section width CW of the bead core (5).

2. A heavy duty radial tyre to be mounted on a five-degree-taper rim (Js) according to claim 1, characterised in that the carcass (6) consists of a single carcass ply and the height H2 of the radially outer end of the turnup portion (6B) is 30 to 60 % of the carcass section height Hc.

3. A heavy duty radial tyre according to claim 1 or 2, characterised in that when the tyre is mounted on a standard rim (Js) and the inflated condition is changed from an initially assembled state in which the inner pressure is 0.5 kgf/sq.cm to a normal state in which the inner pressure is standard, the maximum principal strain ε m of the surface of the region between a maximum tyre width point P1 where the outer surface of the tyre is axially outmost and an outer contact point P2 which is the radially outer point of a region of the bead portion contacting with a rim flange is not more than 4%, and the difference (ε m-ε p) between the maximum principal strain ε m of said region and the maximum principal strain ε p at the maximum tyre width point P1 is less than 2%.

4. A heavy duty radial tyre according to claim 1, 2 or 3, characterised in that the bead portion (4) is provided on the axially outer surface of the turnup portion of the carcass ply with a side packing rubber (9) having a 100% modulus Mp of 14 to 65 kgf/sq.cm, and the radially outer end (9t) of the side packing rubber (9) is disposed outside the outer end of the bead apex (8).

5. A heavy duty radial tyre according to any of claims 1 to 4, characterised in that the bead portion (4) is provided with a chafer rubber (10) having a 100% modulus Mc of 55 to 75 kgf/sq.cm, the chafer rubber (10) covering the axially outer surface of the side packing rubber and being exposed in the outer surface of the bead portion and bead seat, and the chafer rubber (10) is connected with a sidewall rubber (14) having a 100% modulus Ms of 10 to 20 kgf/sq.cm and defining the outer surface of the sidewall portion.

6. A heavy duty radial tyre according to any of claims 1 to 5, characterised in that in a normal state in which the tyre is mounted on a standard rim and inflated to a standard inner pressure and loaded with no load, the bead portion (4) comes into contact with a flange arc surface (Jb2), the flange arc surface being curved with a substantially 90 degree arc and extending to the radially outer end of a rim flange surface, the rim flange surface passing a rim width position of the rim flange, and the ratio (St/S) of the contact length St of the outer surface of the bead portion with the flange arc surface to the arc length S of the flange arc surface is 0.2 to 0.70.

7. A heavy duty radial tyre according to any of claims 1 to 6, characterized in that the bead portion (4) has an arc-like curved surface portion, the arc-like curved surface portion sinking towards the inside of the tyre and extending radially outwardly from an outer contact point which is the radially outer point of a region contacting with the rim flange under the normal state, and said ratio (St/S) is 0.4 to 0.65.

8. A heavy duty radial tyre according to claim 6, characterized in that in the bead portion under said normal state, given that R is the intersecting point of a line extending along the minimum distance F between the axially outer surface M of the carcass turnup portion and a 60 degree position P on the flange arc surface which corresponds to the angle of a 60 degree arc from the radially outer end of the rim flange surface with the outer surface of the bead portion, the ratio f/F of the distance f between M and R to the length F of the line is 0.4 to 0.9.

9. A heavy duty radial tyre according to claim 6, characterised in that the bead portion (4) has an interference between the bead seat surface and rim seat surface.

Fig.1

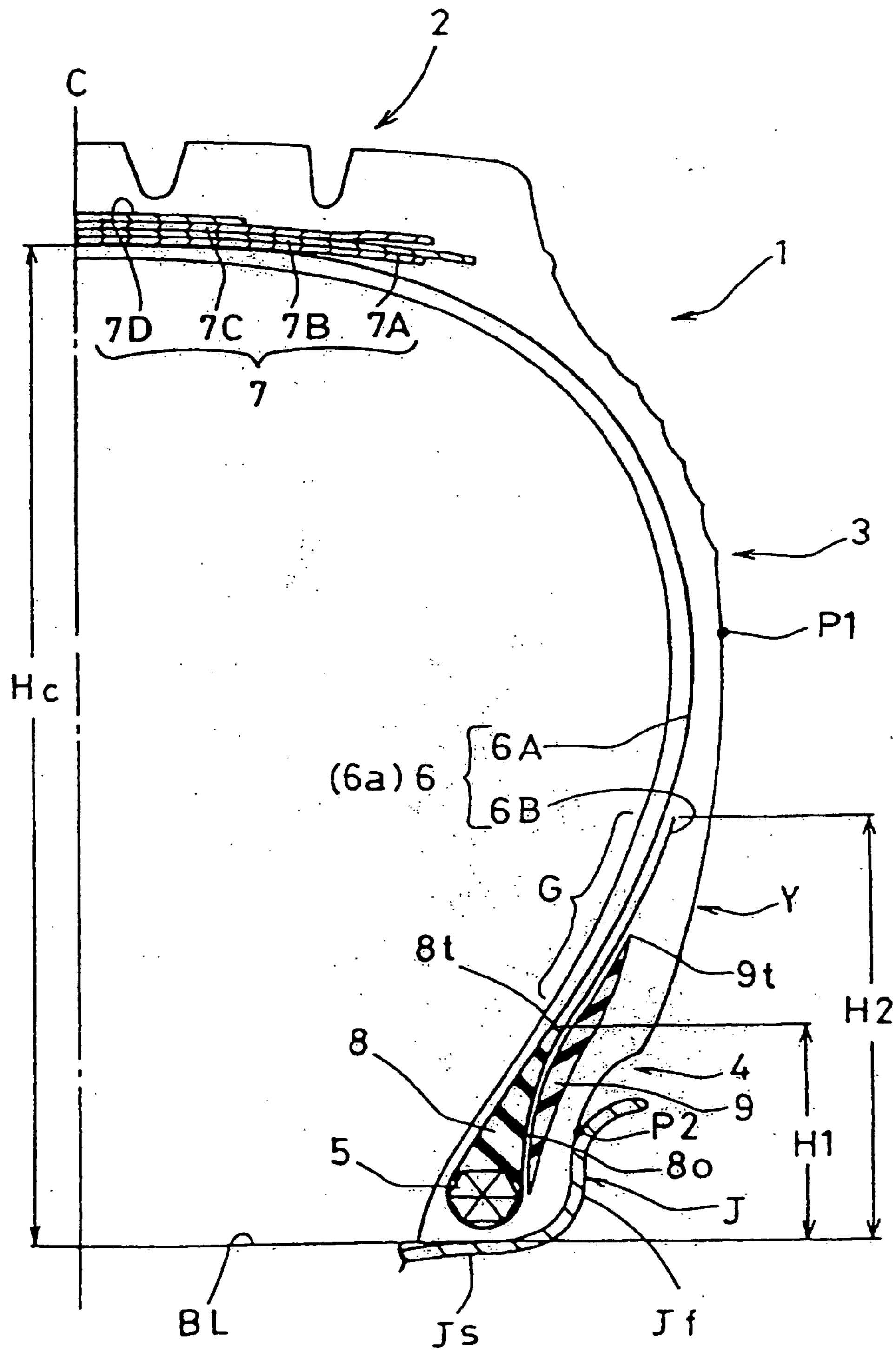
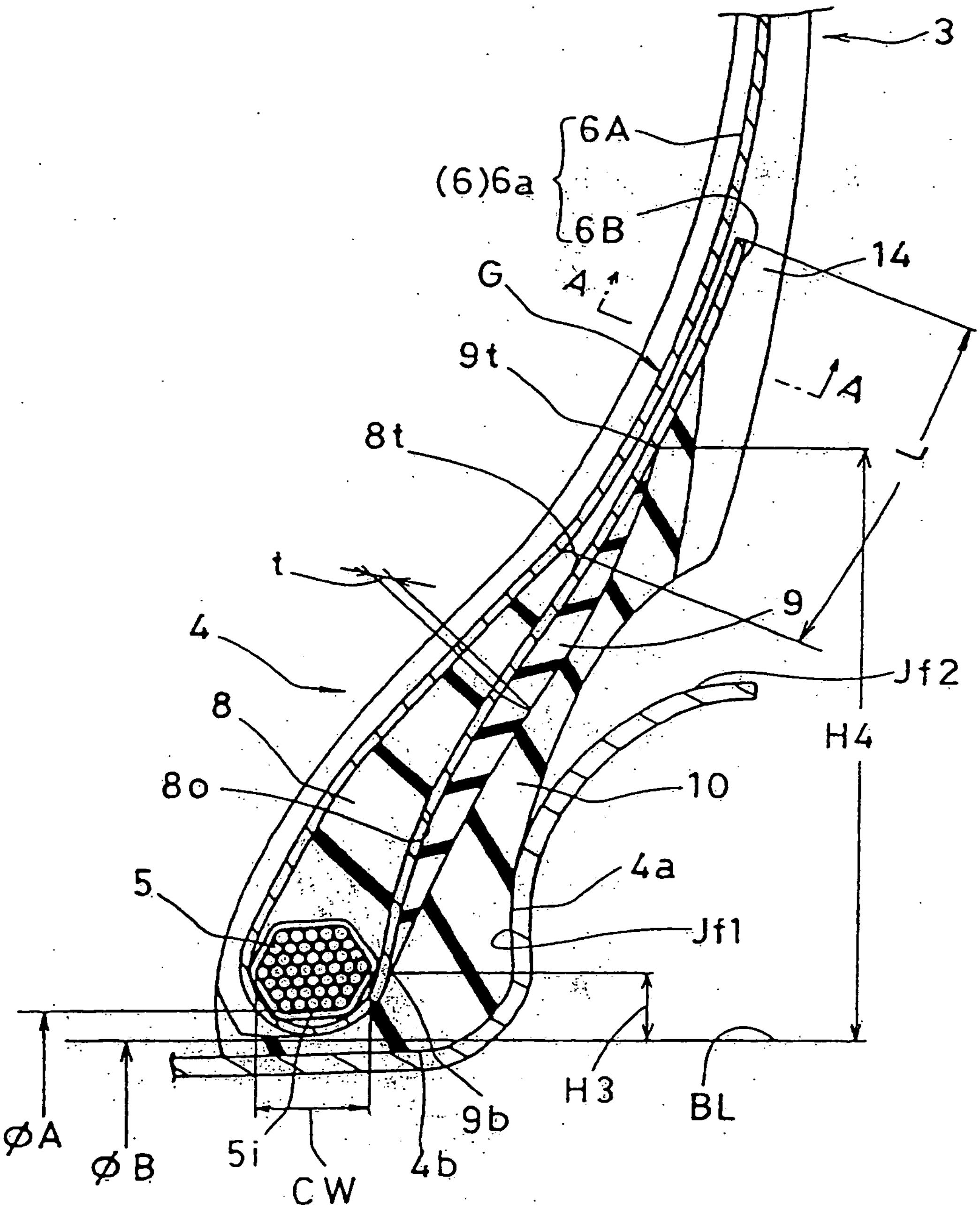


Fig.2


3
6A
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6B
14
G
A
A
9t
8t
t
9
4
Jf2
8
H4
8o
10
5
4a
Jf1
ØA
ØB
5i
CW
4b
9b
H3
BL

Fig.3

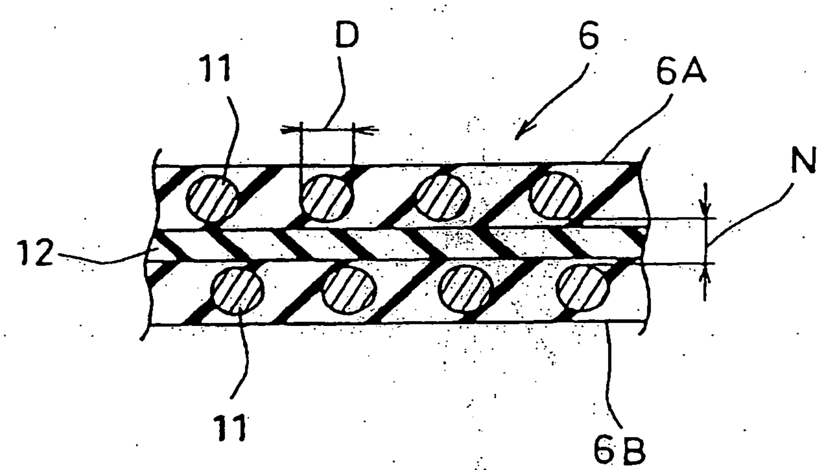
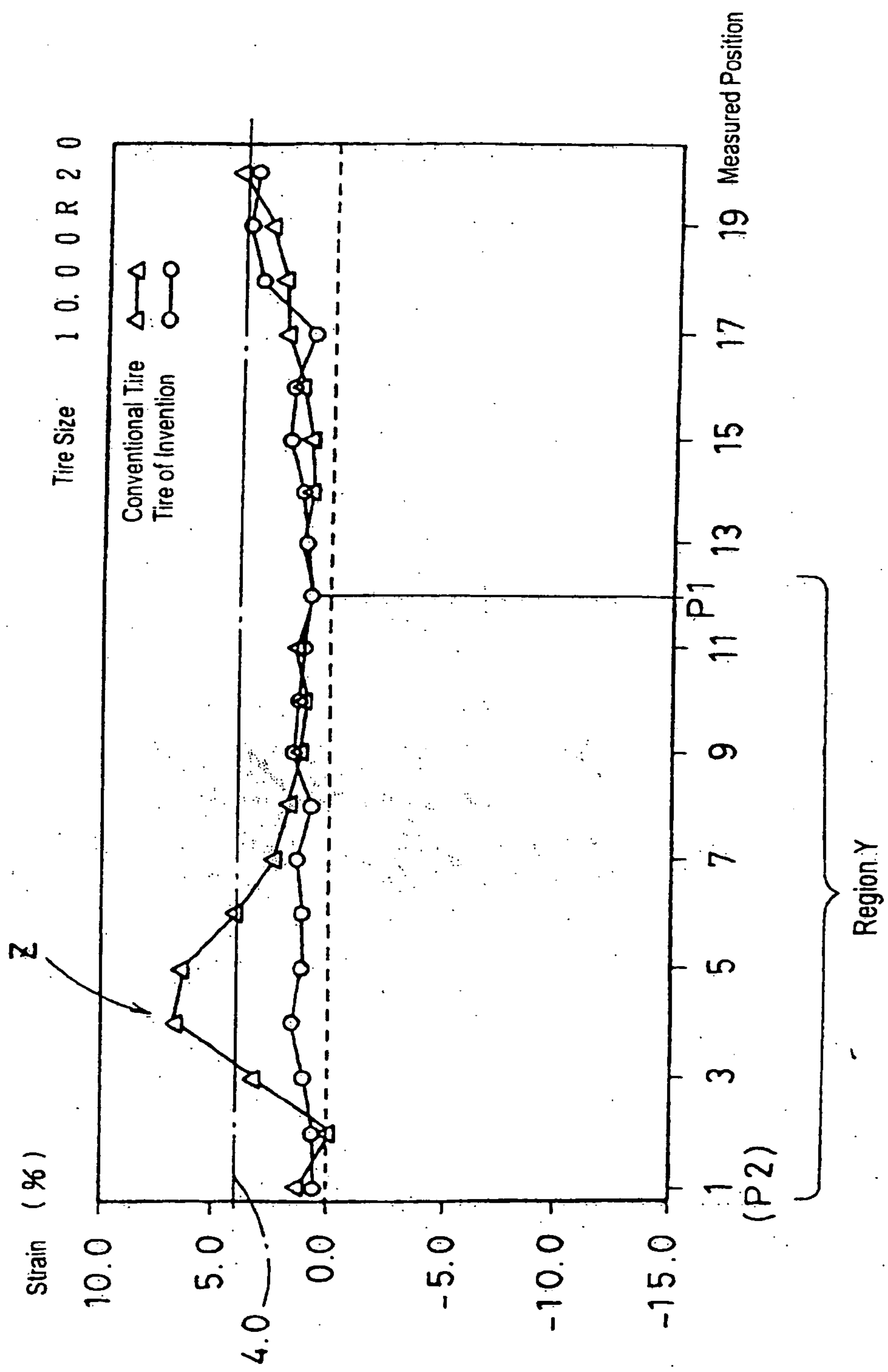


Fig.4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Conventional Tire
Tire of Invention
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5.0
0.0
-5.0
-10.0
-15.0
4.0
Z
1
(P2)
3
5
7
9
11
P1
13
15
17
19
Measured Position
Region Y

Fig.5

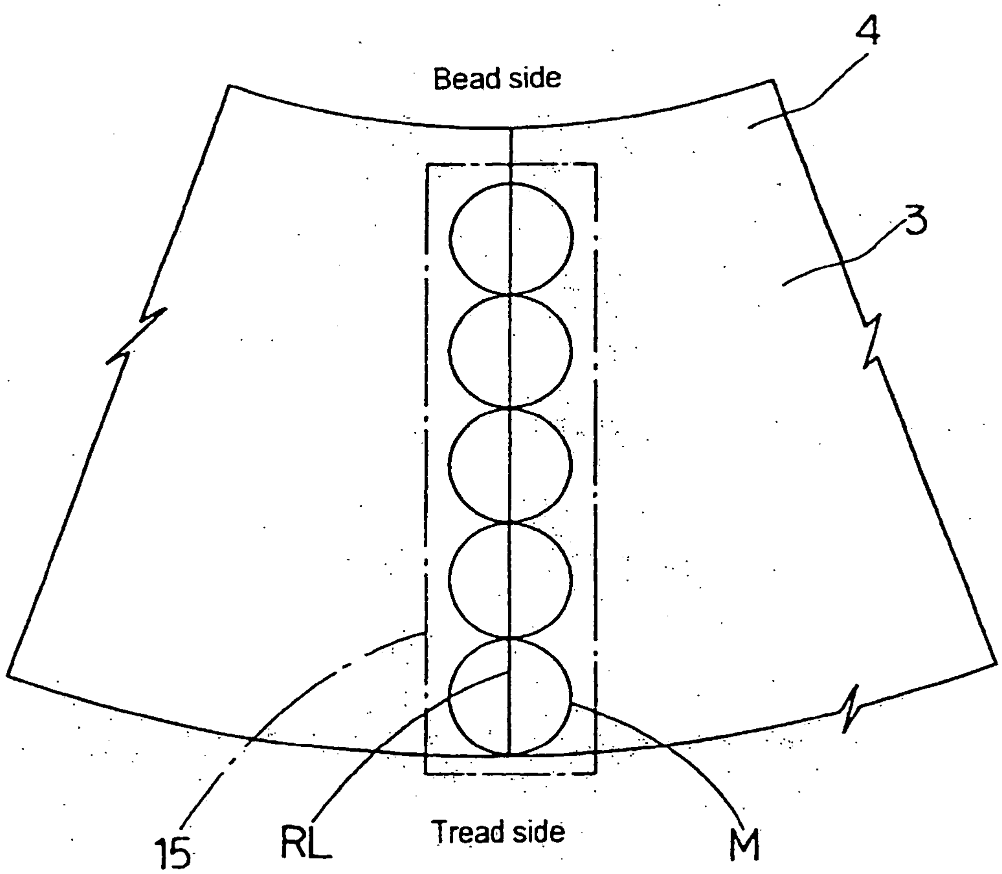
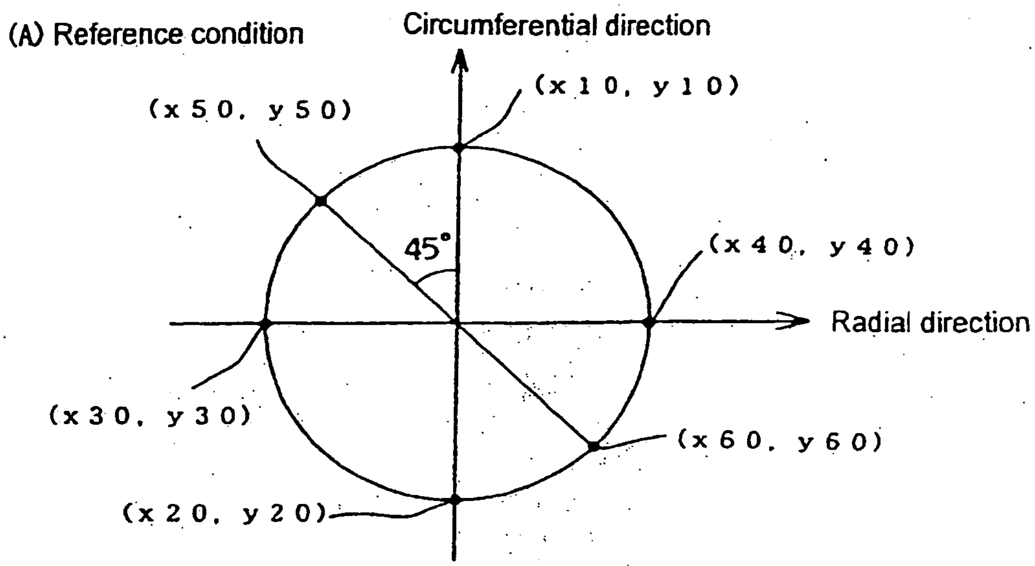


Fig.6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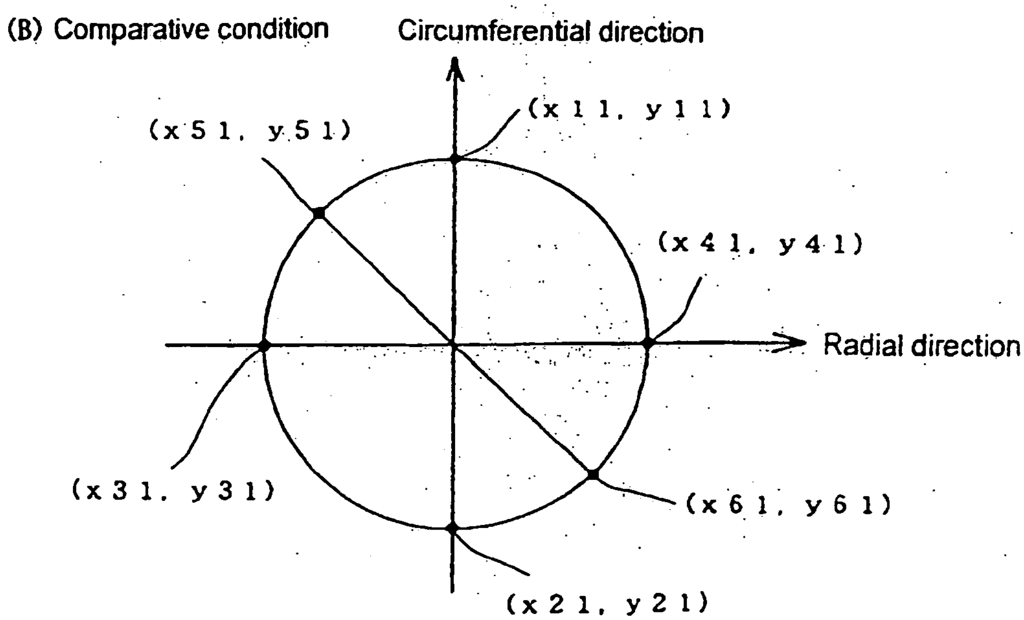
(x 6 0, y 6 0)
(x 2 0, y 2 0)


(B) Comparative condition
Circumferential direction
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(x 5 1, y 5 1)
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Radial direction
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(x 2 1, y 2 1)

Fig.7

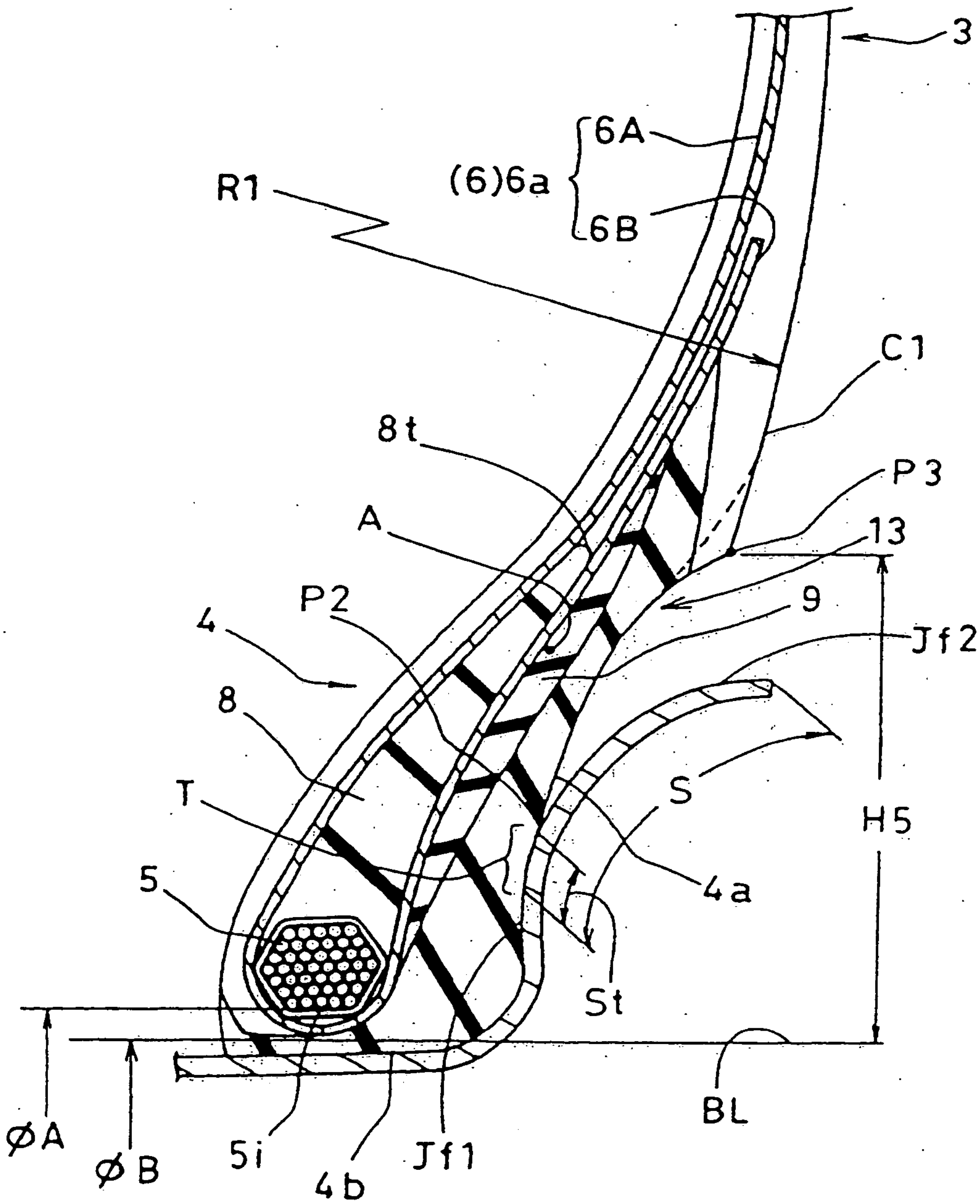
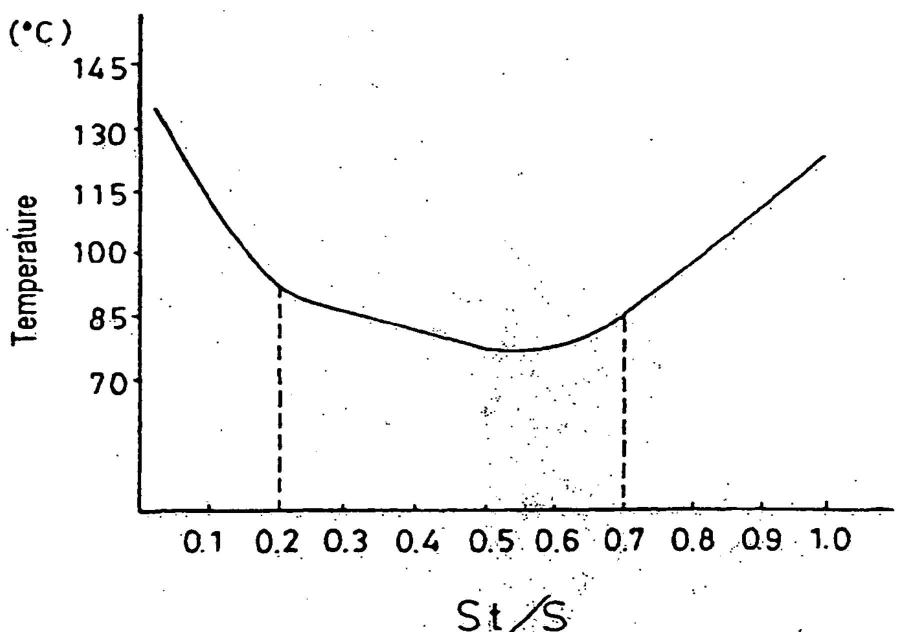


Fig.8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130
115
100
85
70
Temperature
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0.5
0.6
0.7
0.8
0.9
1.0
St/S

Fig.9

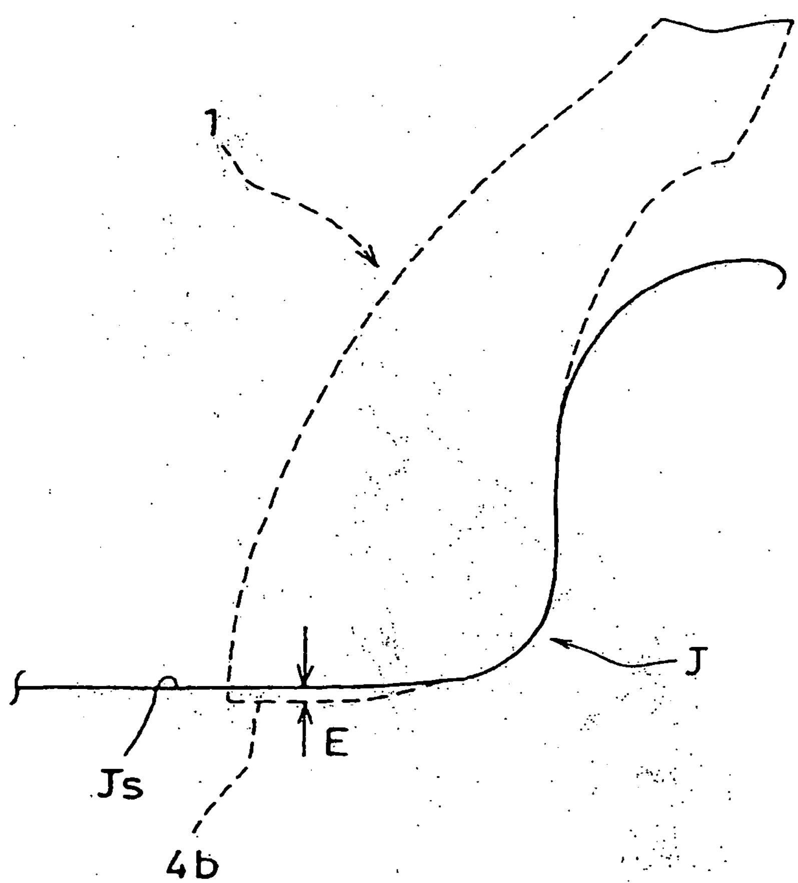


Fig.10

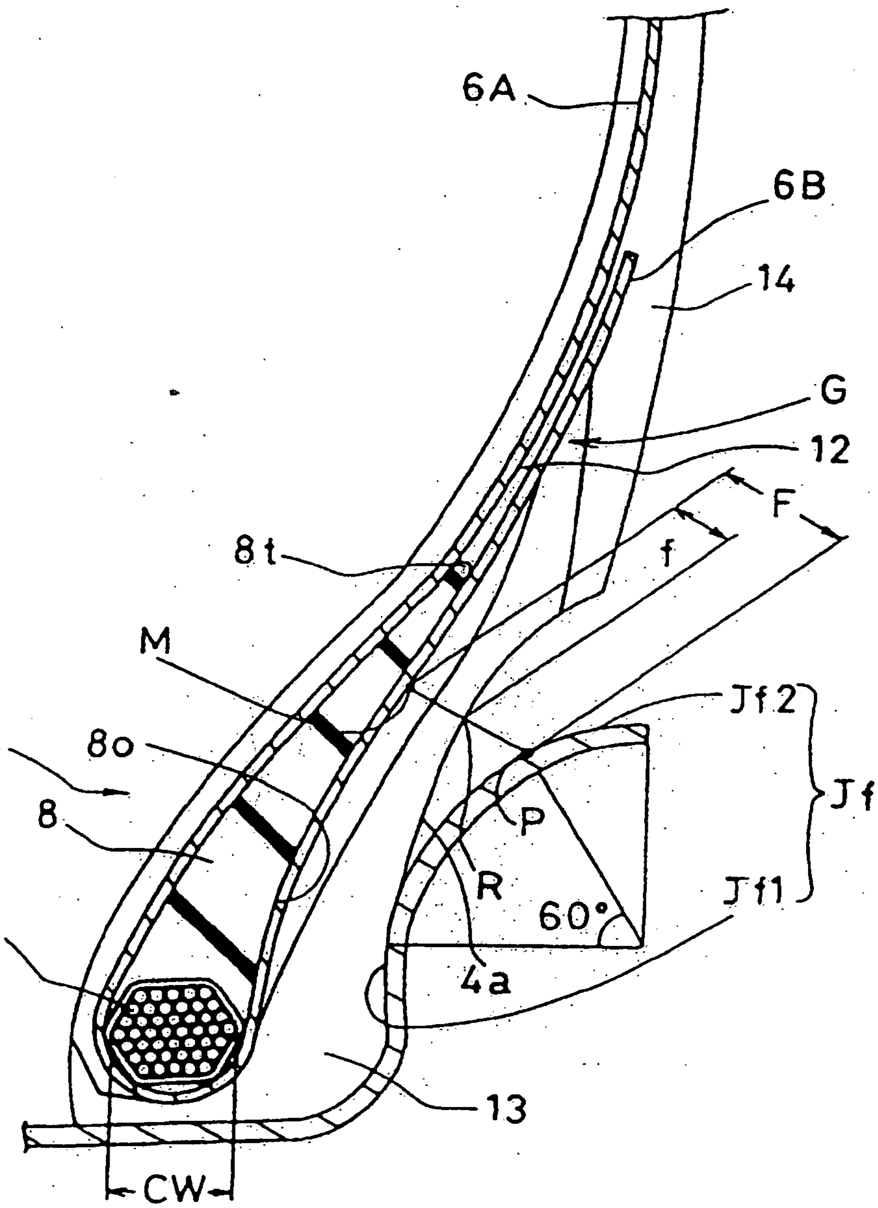


Fig.11

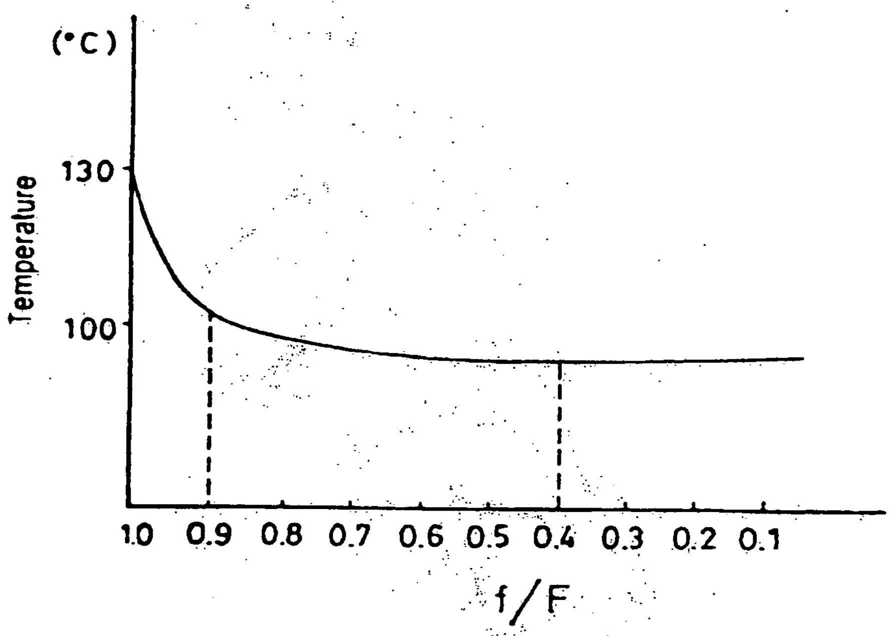
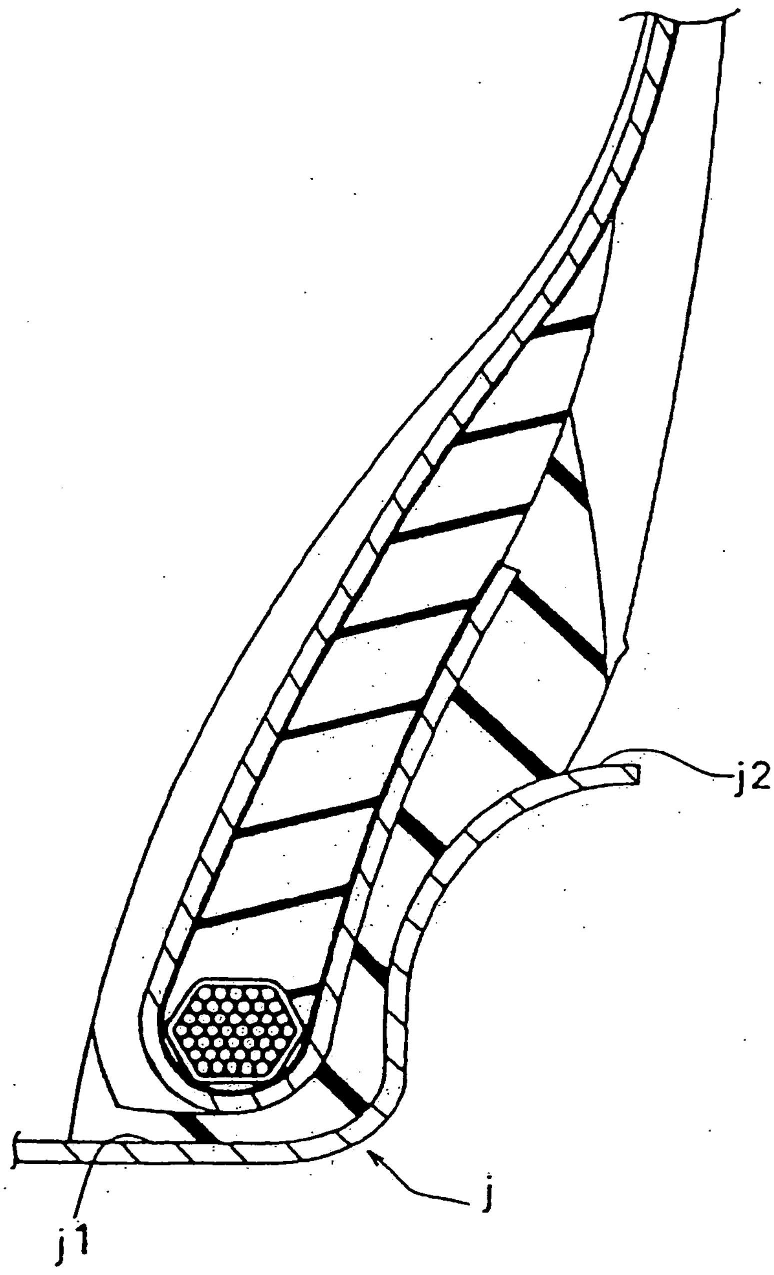


Fig.12



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/02950

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[6] B60C15/00, 15/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[6] B60C15/00, 15/06

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926-1996	Toroku Jitsuyo Shinan Koho	1994-1998
Kokai Jitsuyo Shinan Koho	1971-1995	Jitsuyo Shinan Toroku Koho	1996-1998

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 3-204313, A (Sumitomo Rubber Industries, Ltd.), September 5, 1991 (05. 09. 91) (Family: none)	1-9
Y	JP, 8-230419, A (Sumitomo Rubber Industries, Ltd.), September 10, 1996 (10. 09. 96) (Family: none)	1-9
Y	JP, 8-25923, A (Sumitomo Rubber Industries, Ltd.), January 30, 1996 (30. 01. 96) (Family: none)	1-9
Y	JP, 7-276929, A (Sumitomo Rubber Industries, Ltd.), October 24, 1995 (24. 10. 95) (Family: none)	1-9
Y	JP, 7-17219, A (Bridgestone Corp.), January 20, 1995 (20. 01. 95) (Family: none)	1-9
Y	JP, 4-66309, A (Sumitomo Rubber Industries, Ltd.), March 2, 1992 (02. 03. 92) & EP, 465188, B1 & US, 5415216, A & DE, 69103831, C0	1-9

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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